Fuel System Reliability - Pipeline Compressor Stations & Small Gas Turbines

Anthony J. Smalley

Southwest Research Institute

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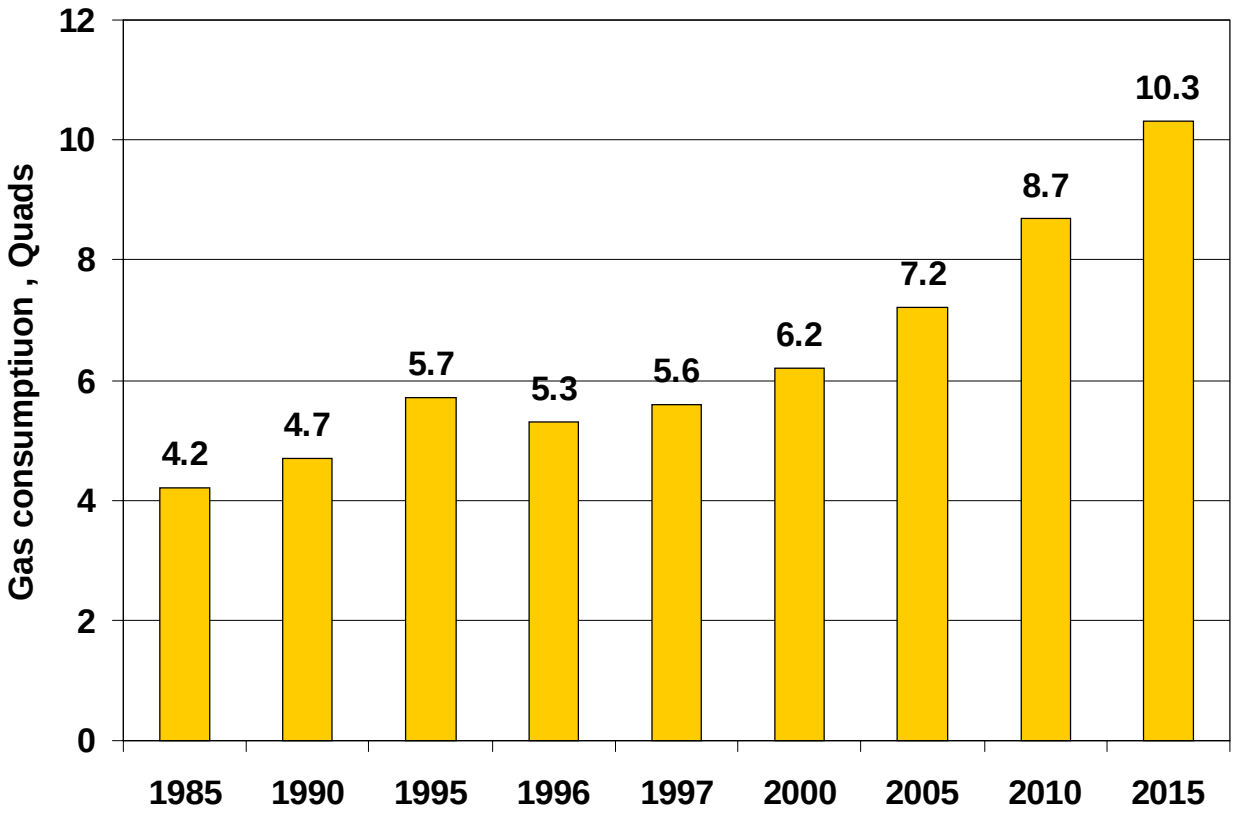
Themes

- Gas-Fired Power Plants and Pipelines: A Tightly Linked Gas Energy System
- Electric Power Reliability and Availability require:
  - Power Plant Equipment Reliability, as well as…
  - Reliability of Pipeline Gas Delivery
- Both Power and Pipeline Industries use Gas Turbines
- Gas Turbine RAM and Condition Monitoring Technologies Benefit both Industries and Contribute to U.S. Energy Reliability
- Pipelines Need New Compression Concepts

Some Observable Trends in the U.S. Gas Energy System

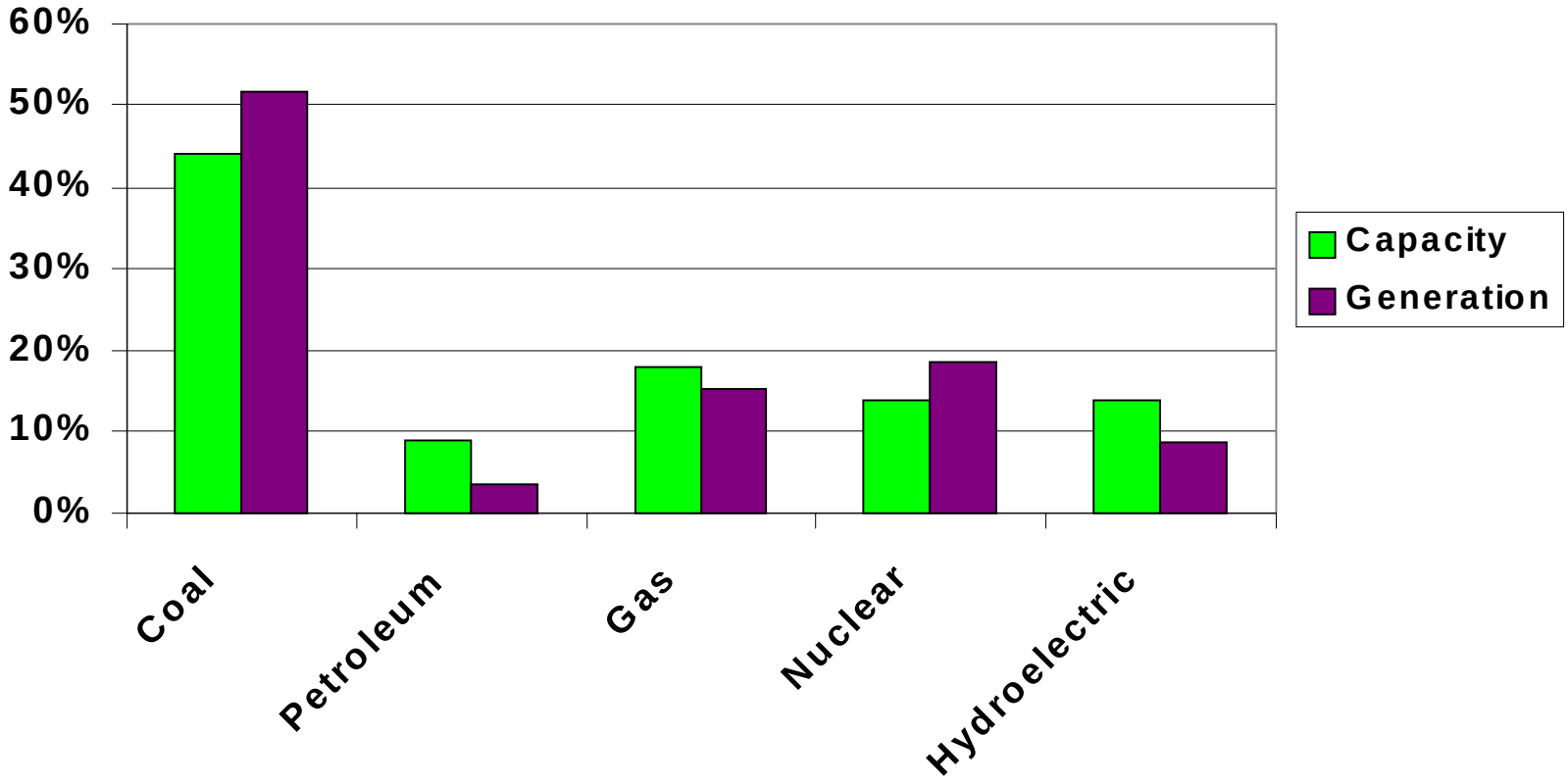
- **Growth in Gas Consumption:**
  - **From 22 TCF Now to 30 by 2015 or Sooner and…to 35 by 2020?**
- **Majority of Growth for GT Power Plants**
- **Nuclear and Coal still 1st Dispatched, so:**
  - **GT Power Plant Load is Variable**

Growth in Gas Consumption for Electric Power Projected Through 2015 (GRI)

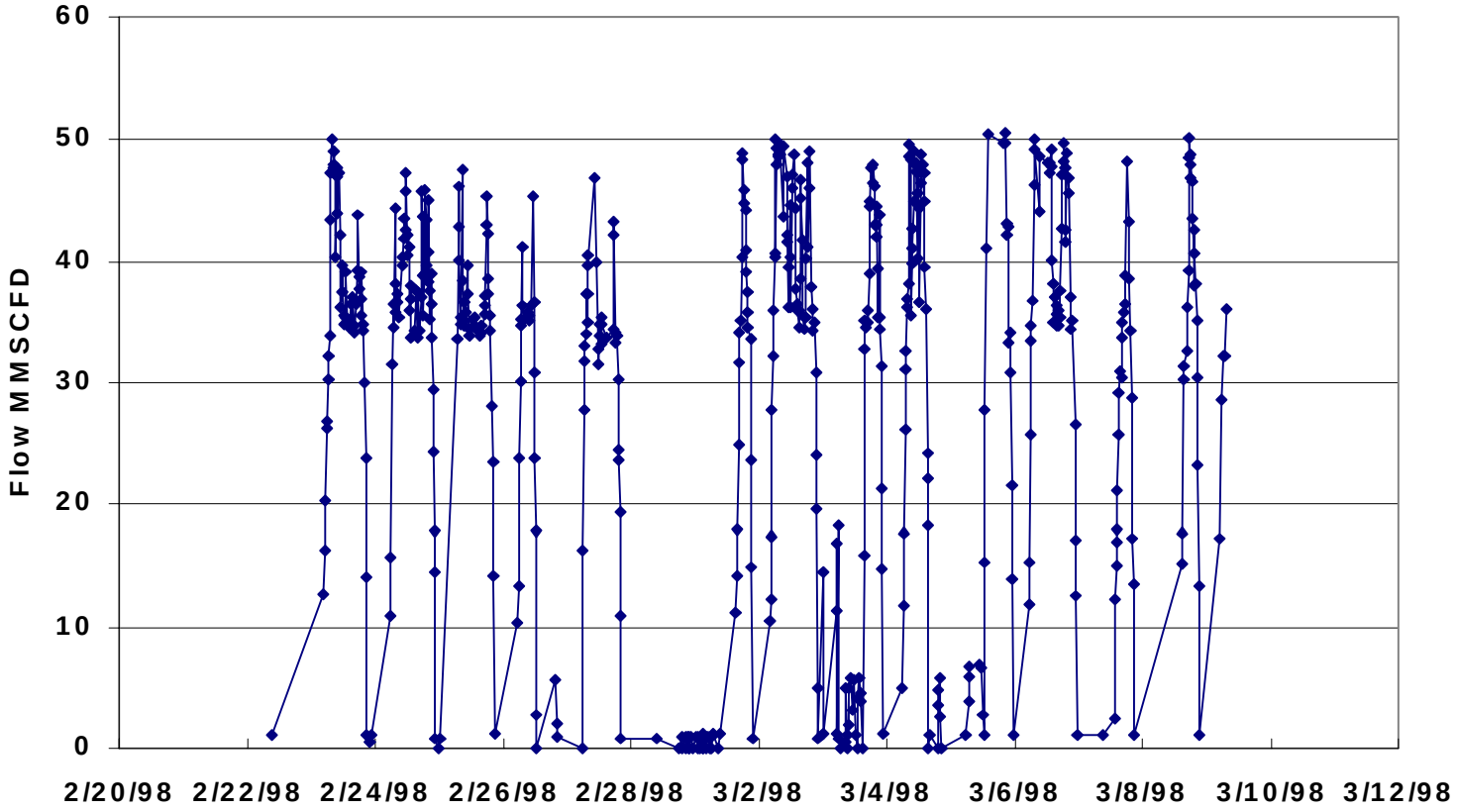


500 MW GTCC Plant with Two GE Frame 7FAs

1998 Generation Capacity & Actual Generation (EIA)



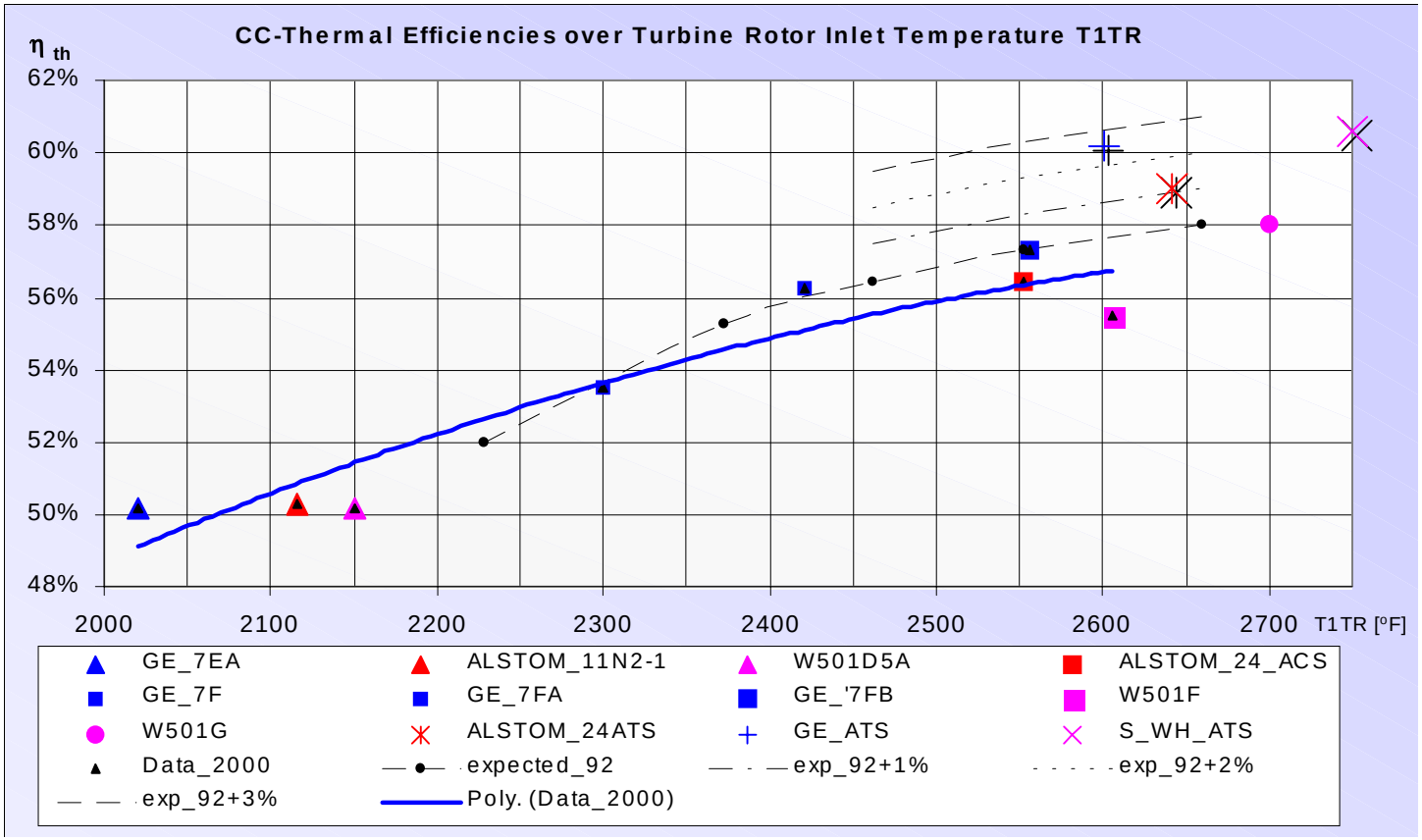
Typical & Representative Power Plant Flow Variation Over 3 Weeks



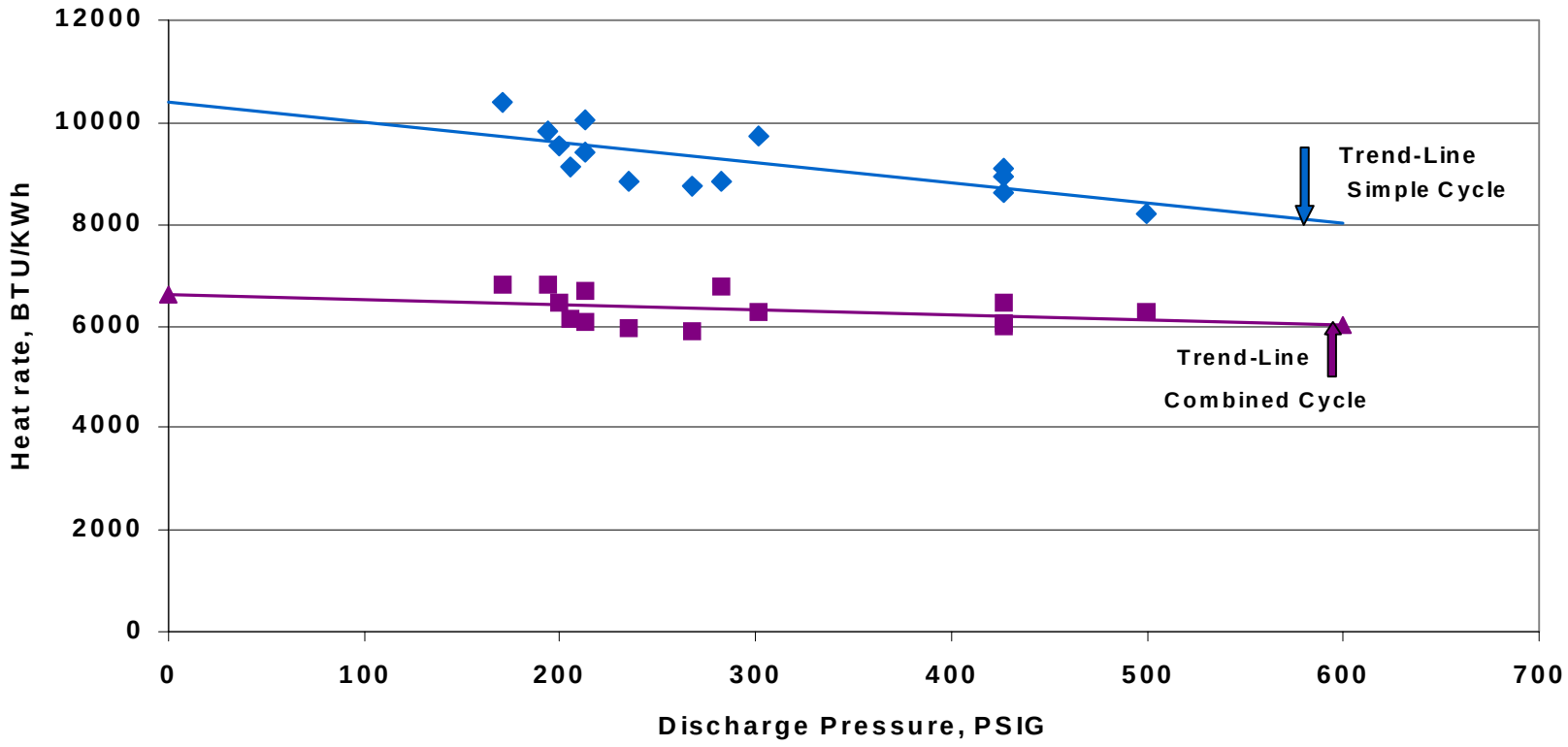
Fuel Gas Conditioning includes Filter / Separators / Heaters / Compression

Large GT Efficiency *vs.* Rotor Inlet Temperature (°F)

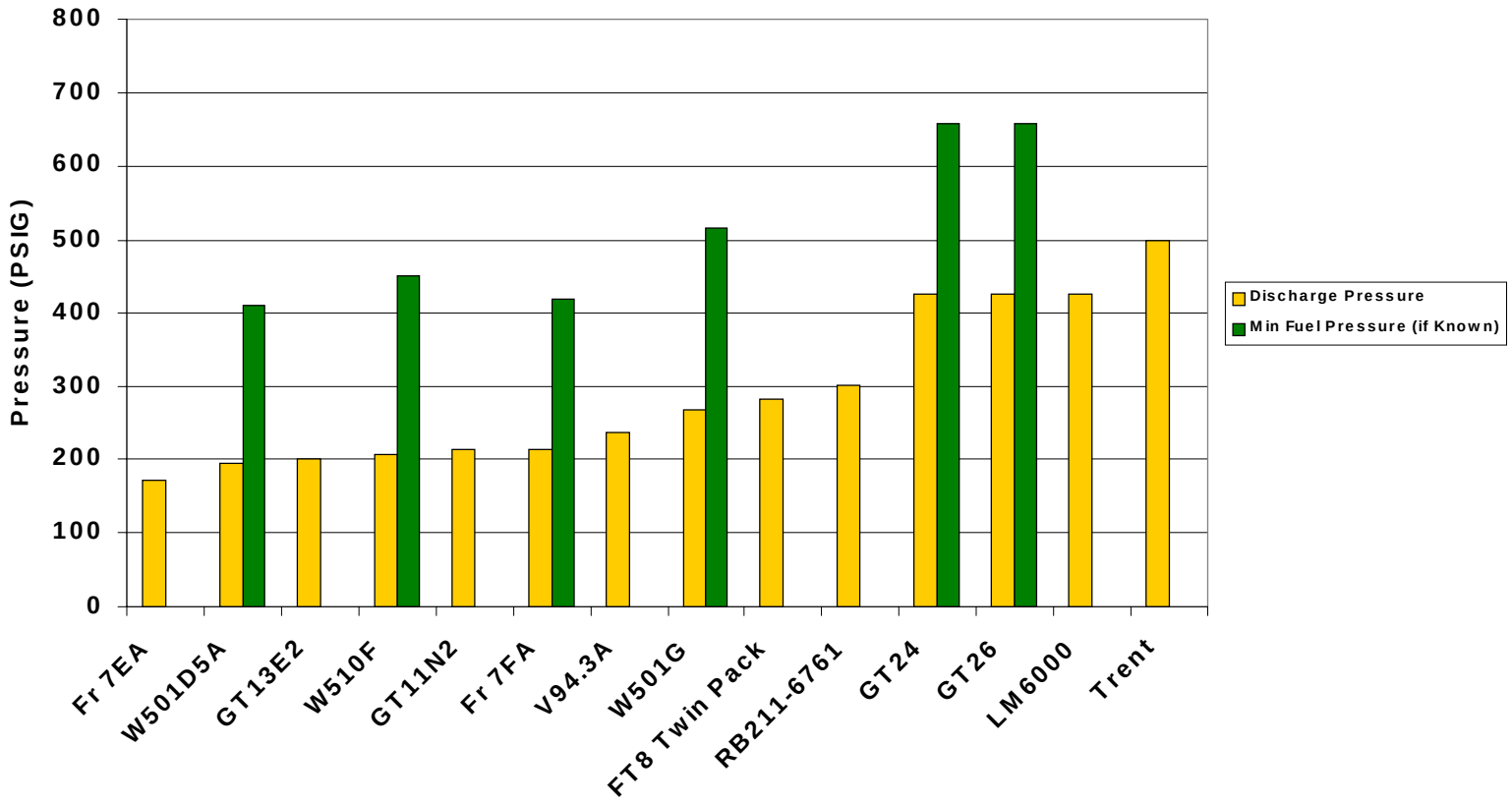
OEM & DOE-ATS R&D



Heat Rate *vs.* Compressor Discharge Pressure for Large CTs in Simple & Combined Cycle

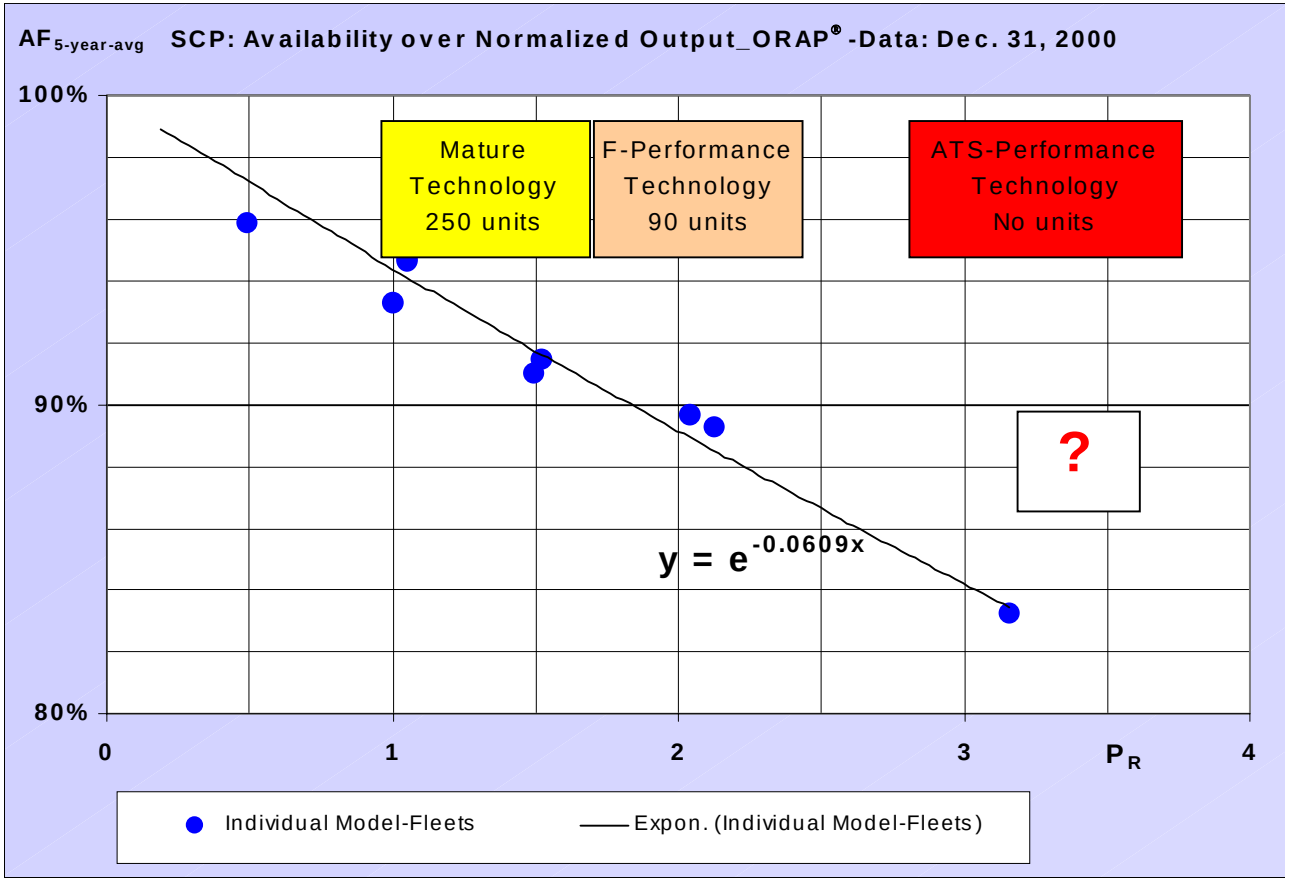


Compressor Discharge & Minimum Fuel Pressure (where known) for Large Combustion Turbines



Fuel Gas Lines to Turbines, Supplying Dry Gas, Whenever Needed, at CDP +200

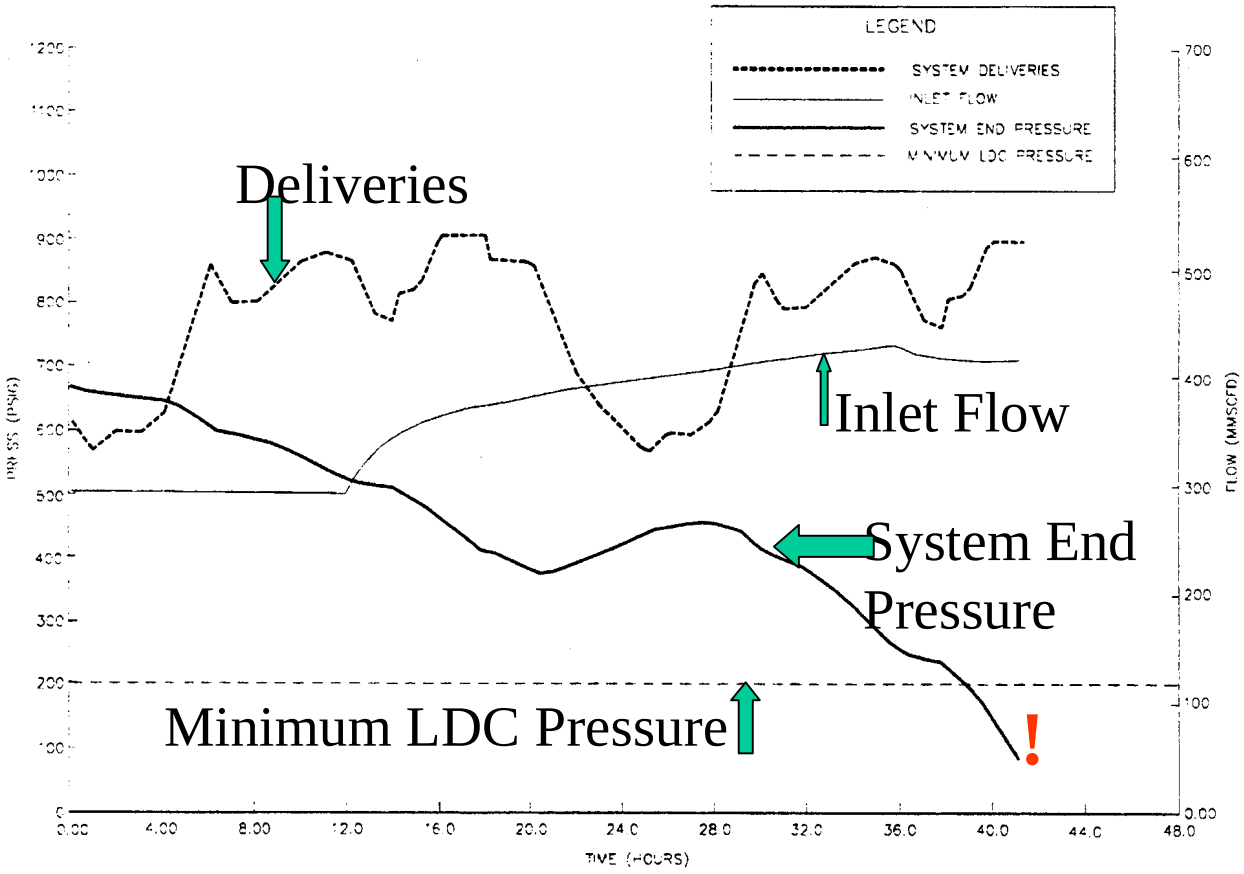
Availability of Normalized Output of GT-Fleets - Power (from SPS-ORAP)



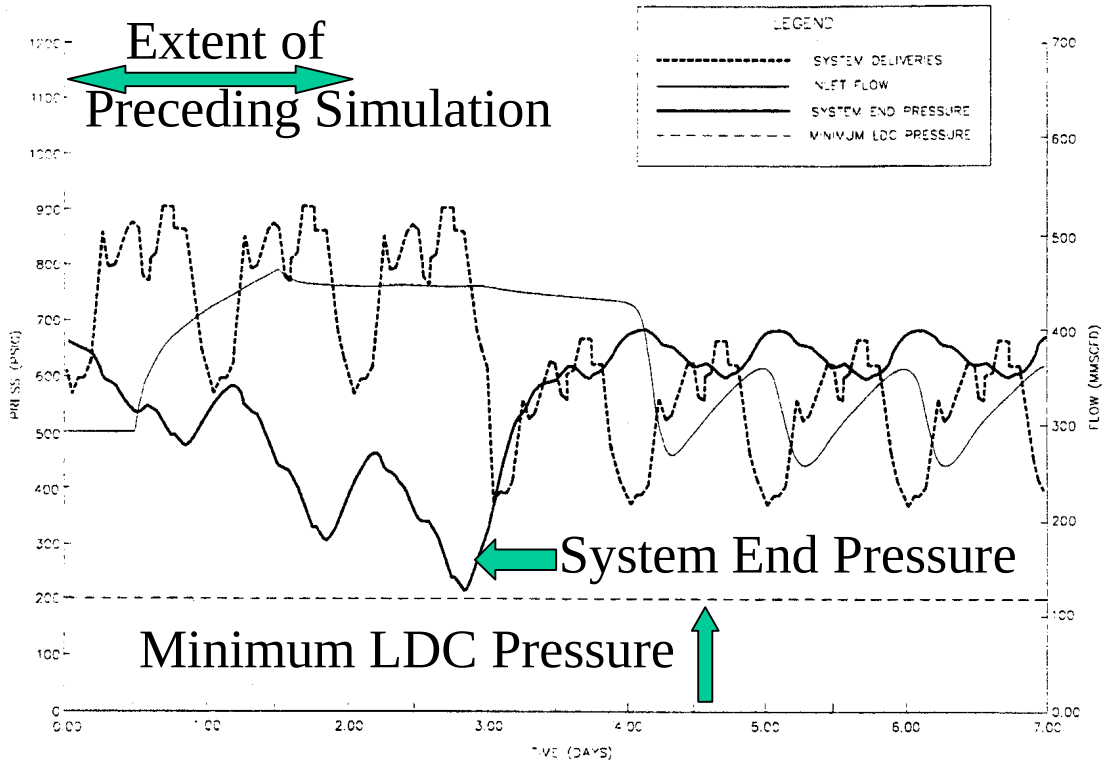
Potential Consequences of Inadequate Compression

- **Result of Simulations by EVA, in "Pipelines to Power Lines Series" (sponsored by GRI/EPRI)…**

Simulations show How Representative System Needs More Compression under Sustained High Demand



Result with 7500 HP More Compression for Peaking



Re-stated, Expanded Trends

- Power System Gas Use Increasing
- GTCC Plants Need at Least Half Gas Growth
- GT Load Variable
- GT Power Market > 30X Mech. Drive Market
- Increasing CDP goes with Lower Heat Rate
- Turbine Inlet = CDP + 200 PSI
- Power Plant Load more Variable and Higher P
- Adequate Compression is Essential for Energy Reliability

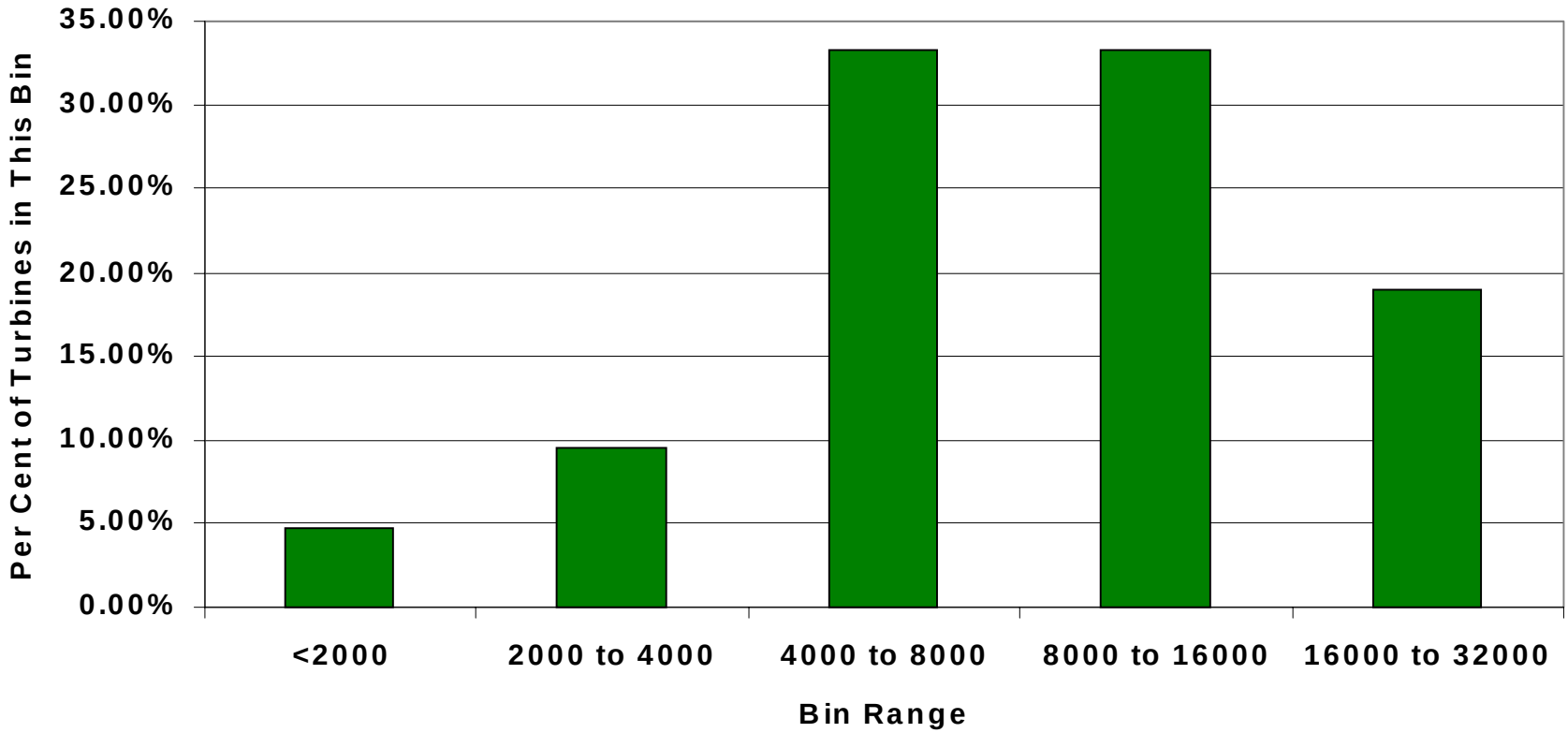
Pipeline Gas Compression Infrastructure - An Essential Element of Energy Reliability

- About 12 GW (16 Million HP)
- Turbines 25% by Population; 45% by Power
- Mostly Old, but will not be Replaced Soon
- Median Pipeline Turbine (~8,000 HP) Larger than Recips, but Smaller than Power Plant Turbines)
- Impacted by Emissions Regulations (NOx/HAPS)
- Burns ~3% of the Gas Delivered to End User
- Cost of Power Dominates True Operational Cost

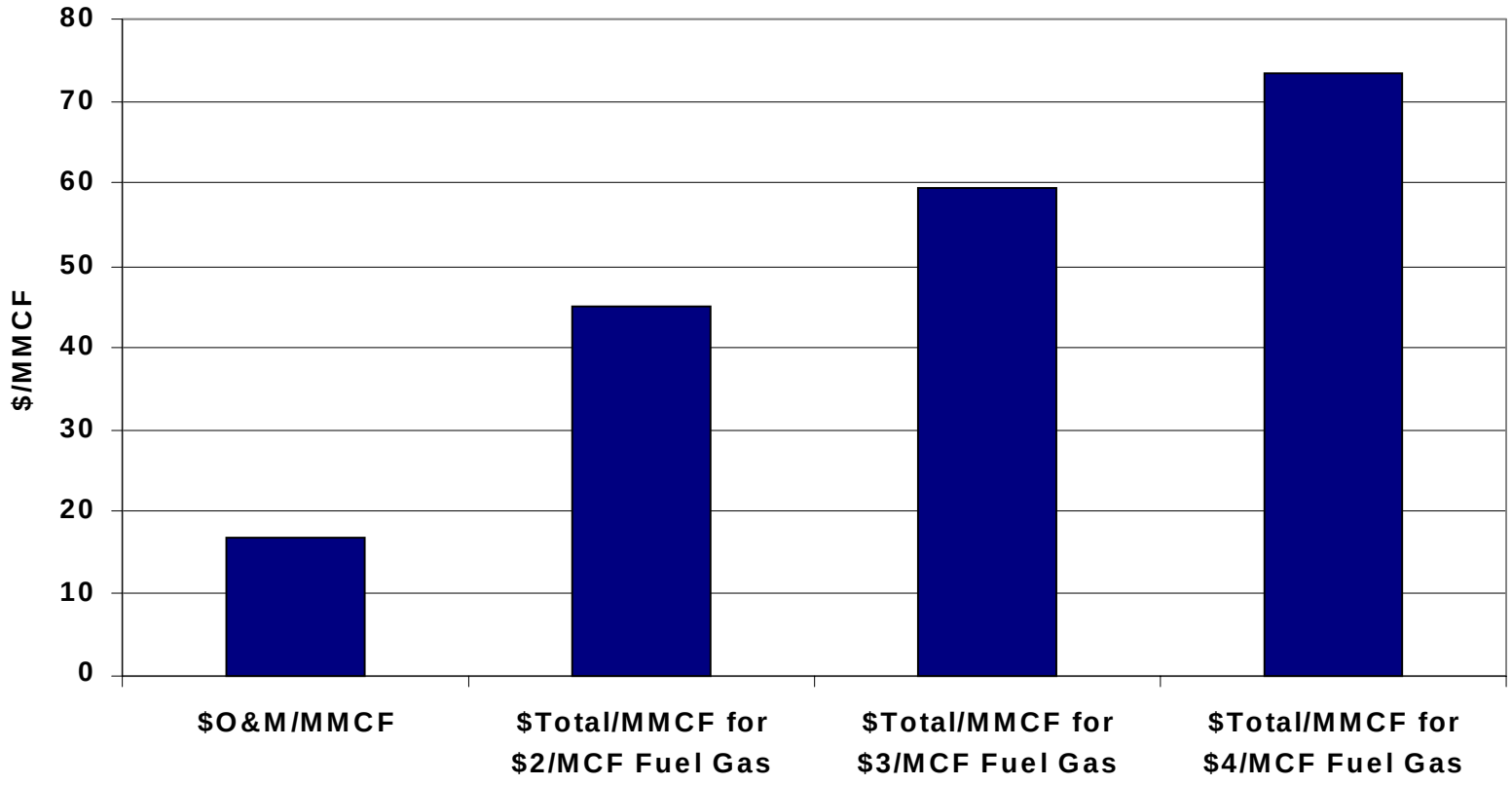
DOE Gas Infrastructure Program - Goals Relevant to Compression

- **Increase Capacity 10% without Changing Infrastructure**
- **Improve Flexibility of System to Respond to Load Changes**
- **Decrease Air Emissions by 50% Per MMSCF by 2010**
- **Develop a Portfolio of Technologies to Reduce Costs:**
  - **Reduce Construction Costs >20% by 2005**
  - **Reduce O&M Costs 30% by 2005; 50% by 2010**

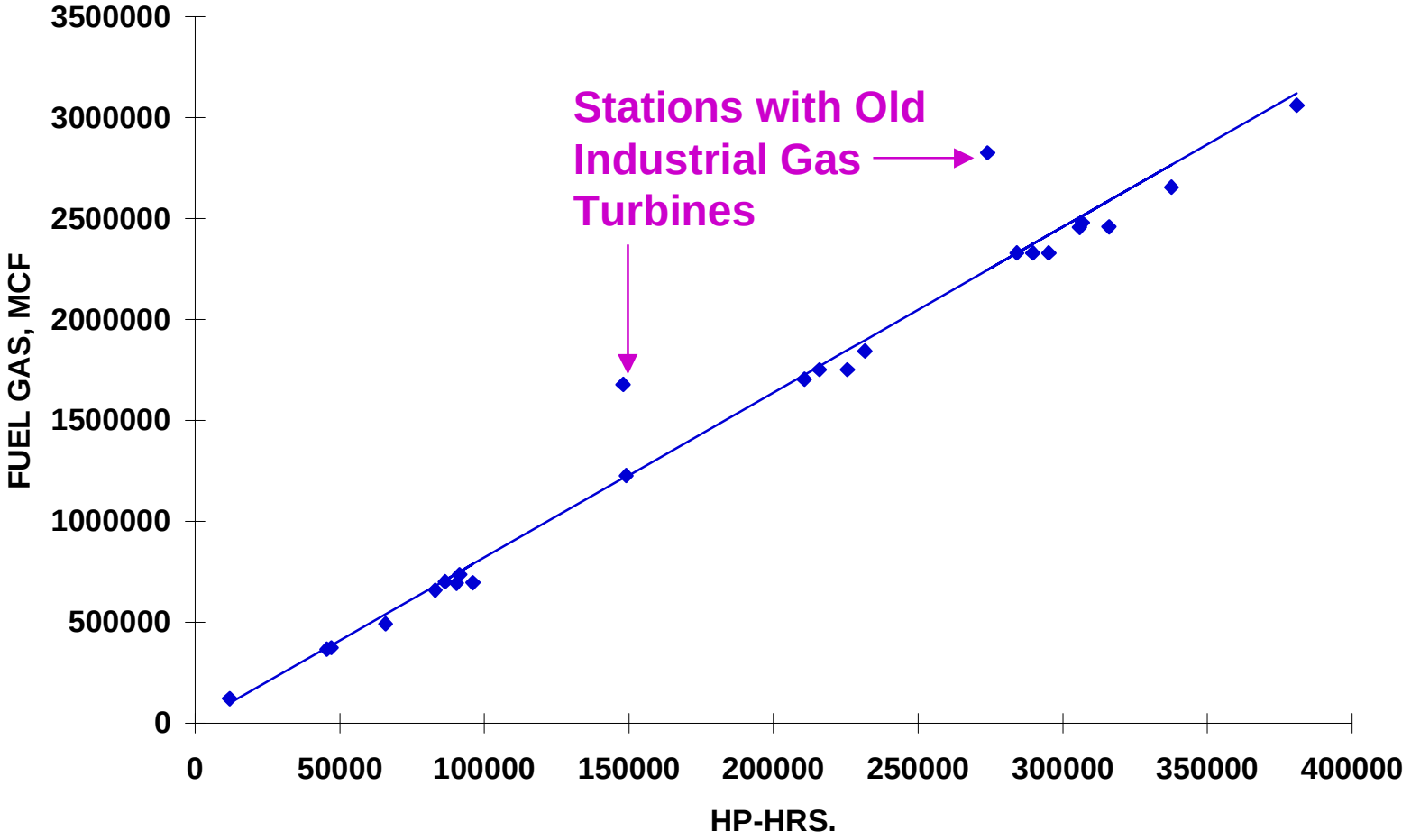
Distribution of HP for Gas Turbines in Gas Transmission Service (approx.)



Pipeline Compression Cost as a Function of Fuel Gas Cost (PRCI) *(based on 1994 records)*



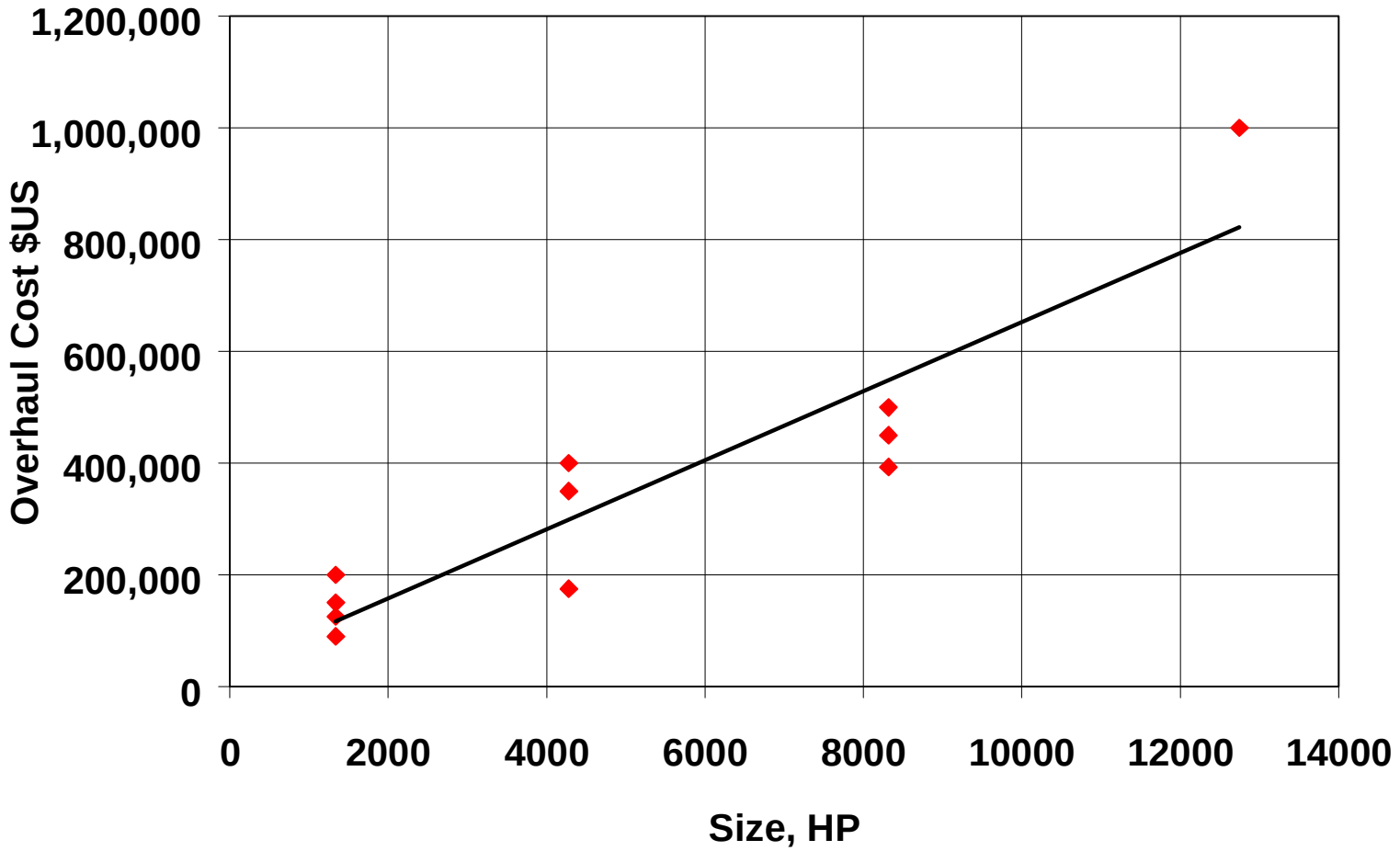
For One Company - Regression of Station Fuel Gas *vs.* Station HP-Hrs. - R^2=96.7; Slope=8.194 MCF/1000 HP-Hr. +/-0.15330



Pipeline Gas Turbines

- ~1100 Gas Turbines in Pipeline Service
- Average Company Fleet >100 Units
- Small Units: Median Power = 6 MW (8,000 HP)
- Significant No. >100,000 Hrs.; Some >300,000
- Mostly 2-Shaft Variable Speed Mech. Drive
- Transition to Digital Controls still Ongoing
- GT Overhauls – Costliest Single Maintenance Item for Pipeline Operators
- Potential Condition Monitoring Concerns: Integrity; Performance; Hot Section Life

Estimated Overhaul Cost of Industrial Gas Turbines by Size (Based on Informal Estimates during Interviews; $ = $34,452 + $61.81 HP)



Pipeline Condition Monitoring Practice

- **Trending Periodic Data, e.g., Vibration and Temperature is increasingly Common, but**
- **Diagnostic/Prognostic Interpretation is Limited**
- **Performance Degradation Assessment Limited for Turbines and Centrifugal Compressors**
- **Life Management of Hot Section Components Essentially Non-Existent**

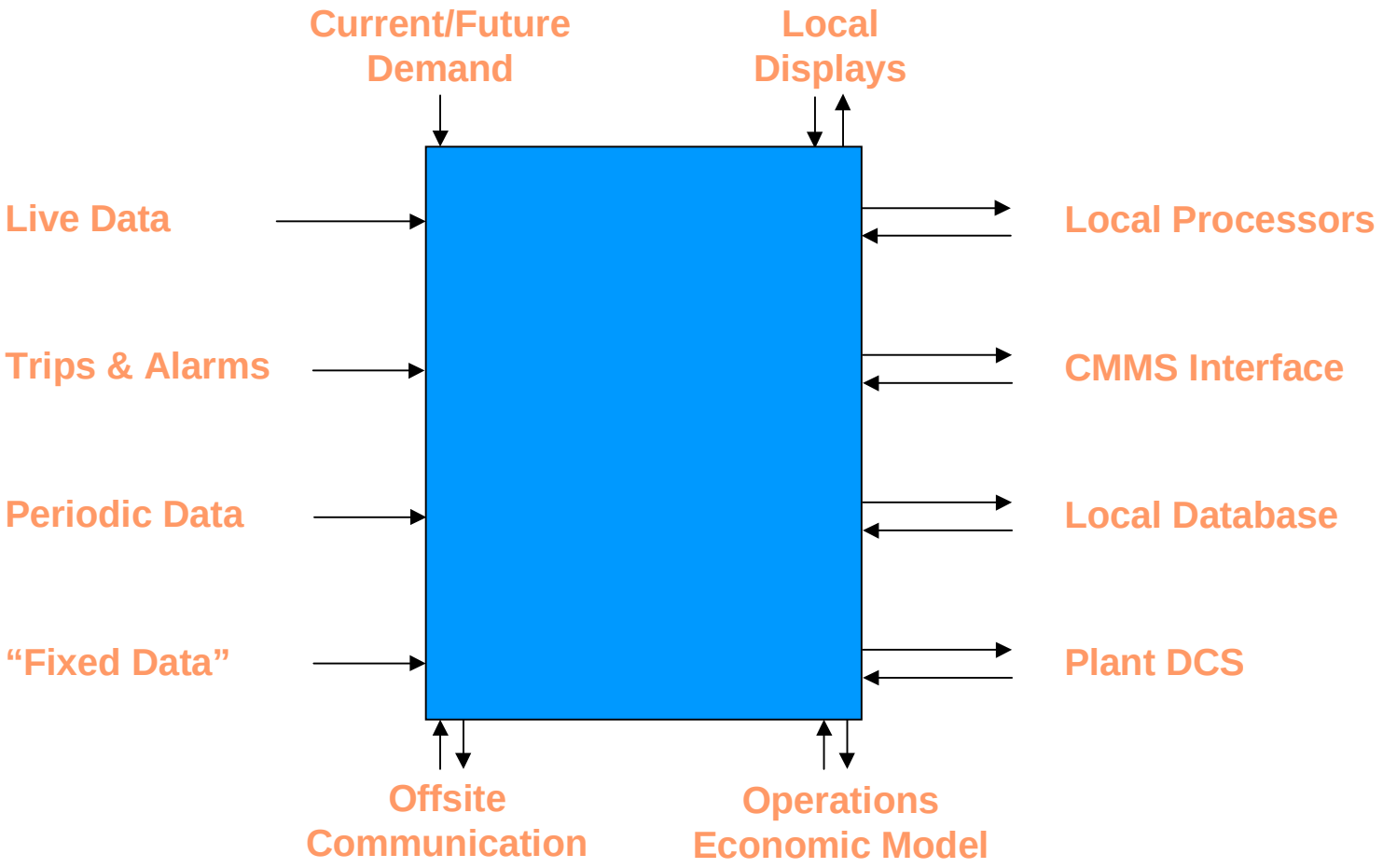
Pipeline Condition Monitoring Practice – *cont'd*

- **Digital Control Systems and MMI/HMIs provide New Opportunities**
- **GMRC, PRCI have Early Concept/Paper Studies**
- **DOE Recently Funded Programs for Large Power Generating Turbines have Potential for Beneficial Tech Transfer to Pipeline Application:**
  - **Coating Life Management**
  - **Prognostics and Diagnostics**

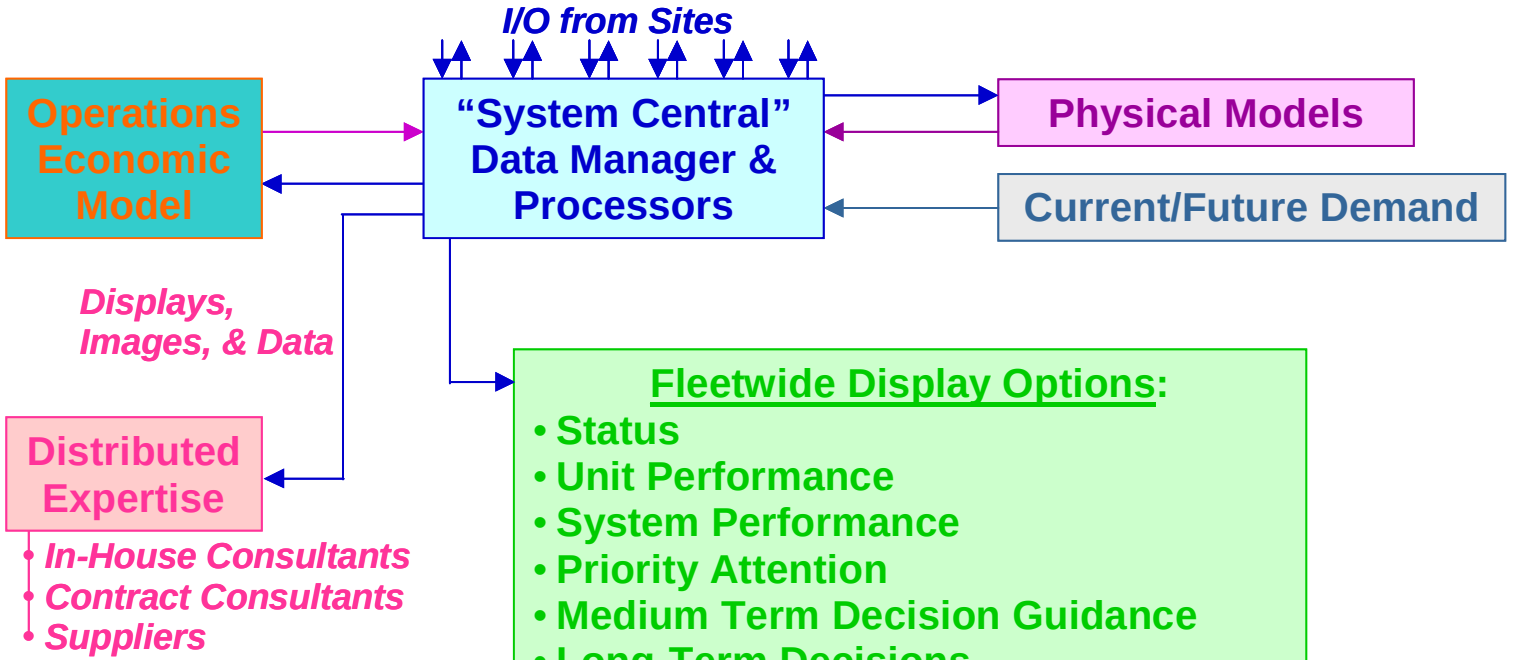
PRCI Program on "Engine/Compressor Performance Data Normalization (ECPDN)" Objective:

- **To Enable Intelligent Interpretation of Compressor Station Digital Data, with:**
  - **Expected Values or Normalized Values based on Changing Conditions,**
  - **Alarms based on Significant Deviation from Expected Values, and**
  - **Operator Action Guidance.**
- **Turbine Parameters include: CDP; Gas Compressor Head and Efficiency; Filter Pressure Drop**

Fleet Monitoring Concept: Local Functional Architecture (GMRC)



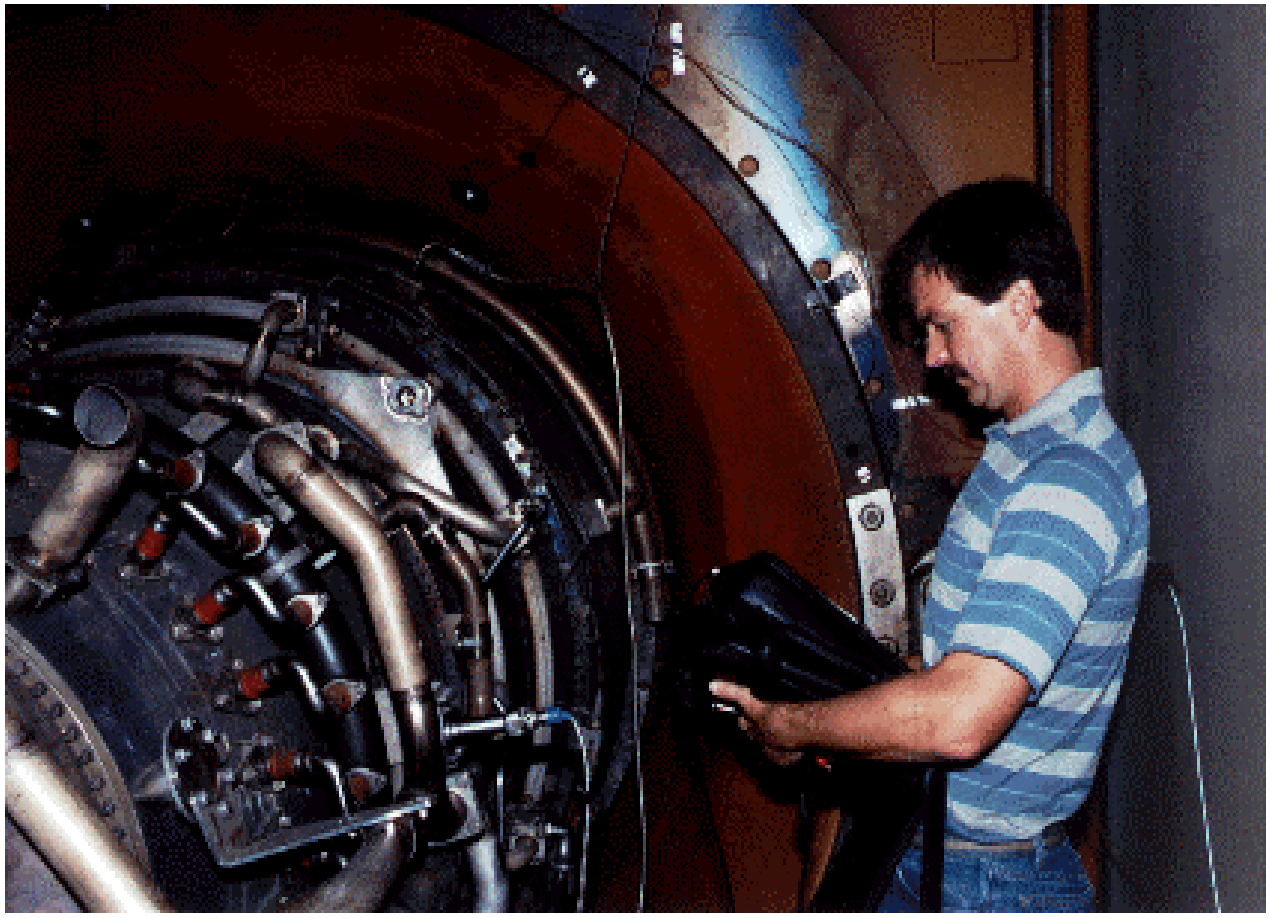
Fleet Monitoring Concept: Remote System Functional Architecture (GMRC)



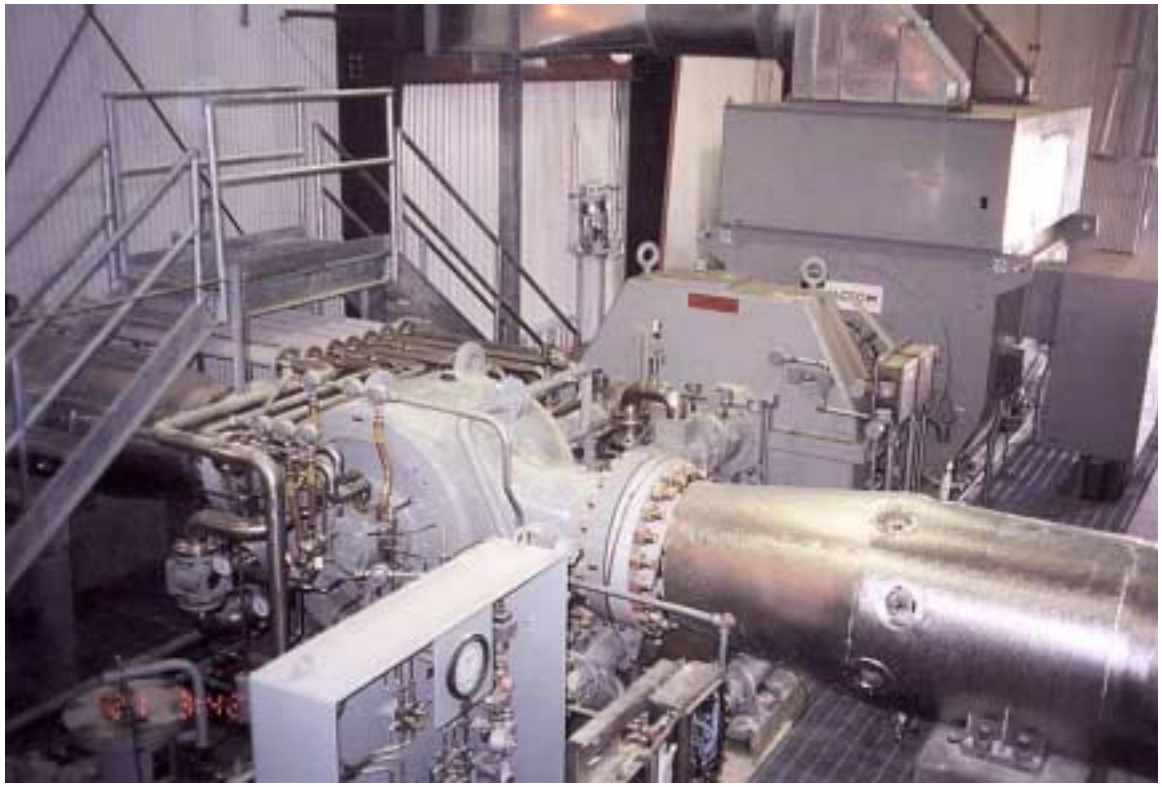
Anticipated New Compression: ~4.1 GW (5.5 Million HP) by 2015

- Engine Driven Recips
- Motor Driven Recips
- Gas Turbine Driven Centrifugals
- Motor Driven Centrifugals

Pipeline Gas Turbine Driver



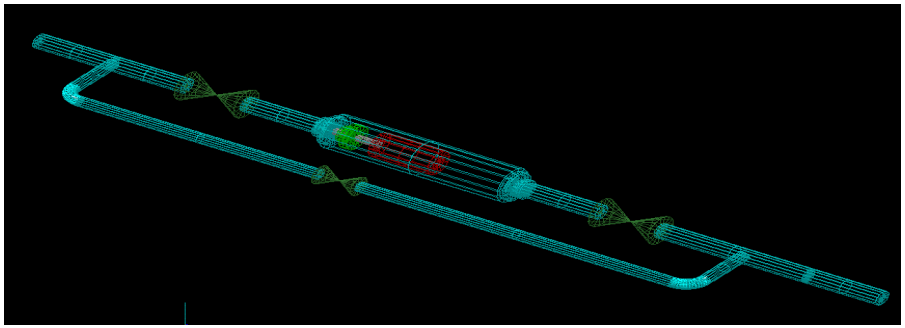
Pipeline Motor-Driven Centrifugal + Gearbox Speed Increaser

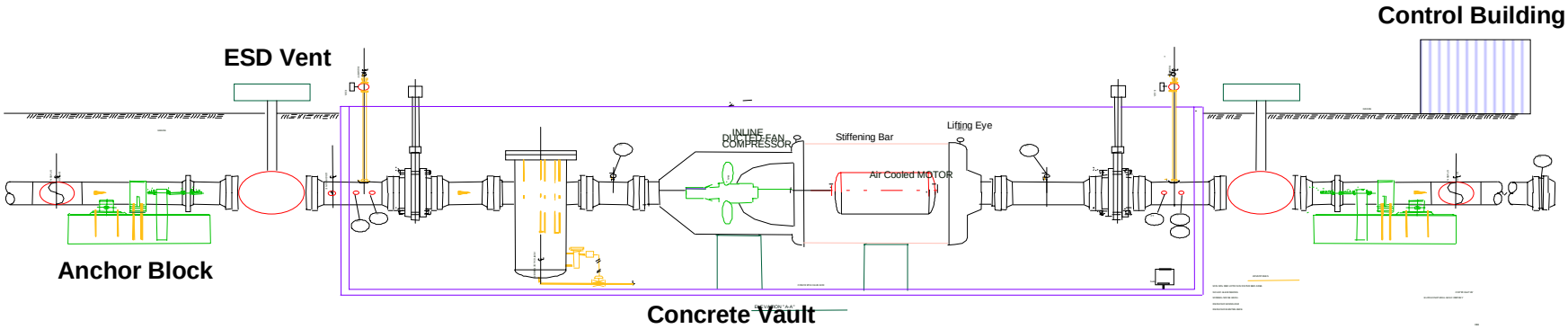


Engine Driven Reciprocating Compressor Installation

Motor Driven Reciprocating Compressor Installation

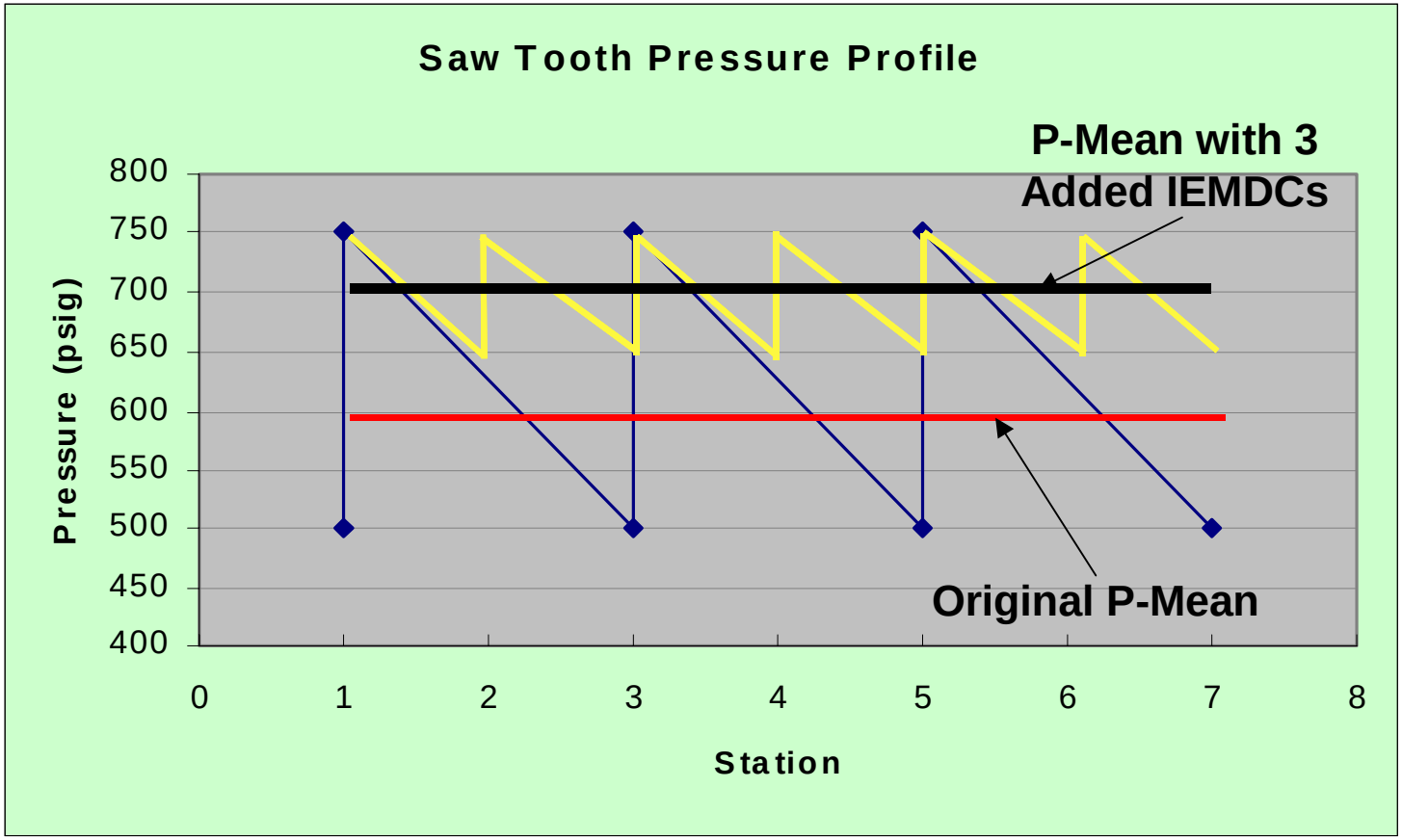
Advanced Pipeline Compression Concept: The In-line Electric Motor Driven Compressor "IEMDC"



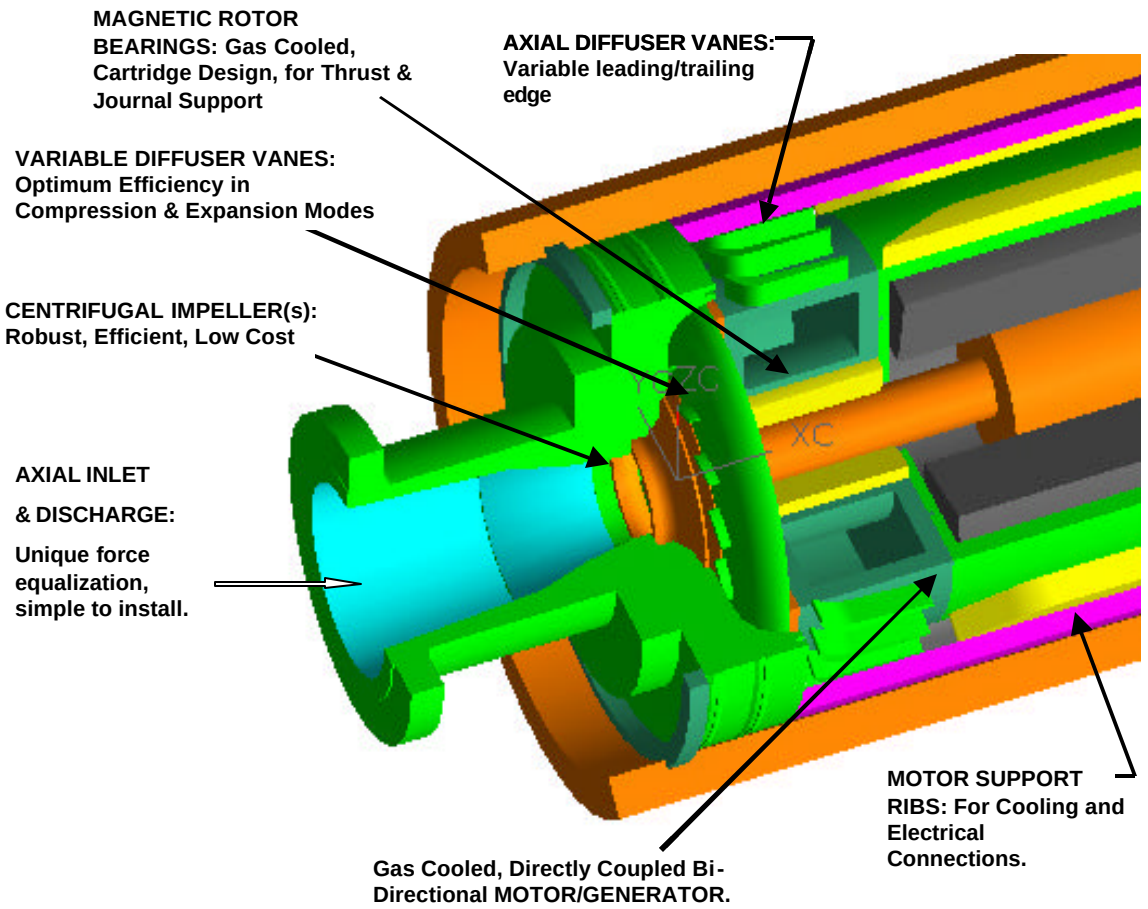


Elevation View

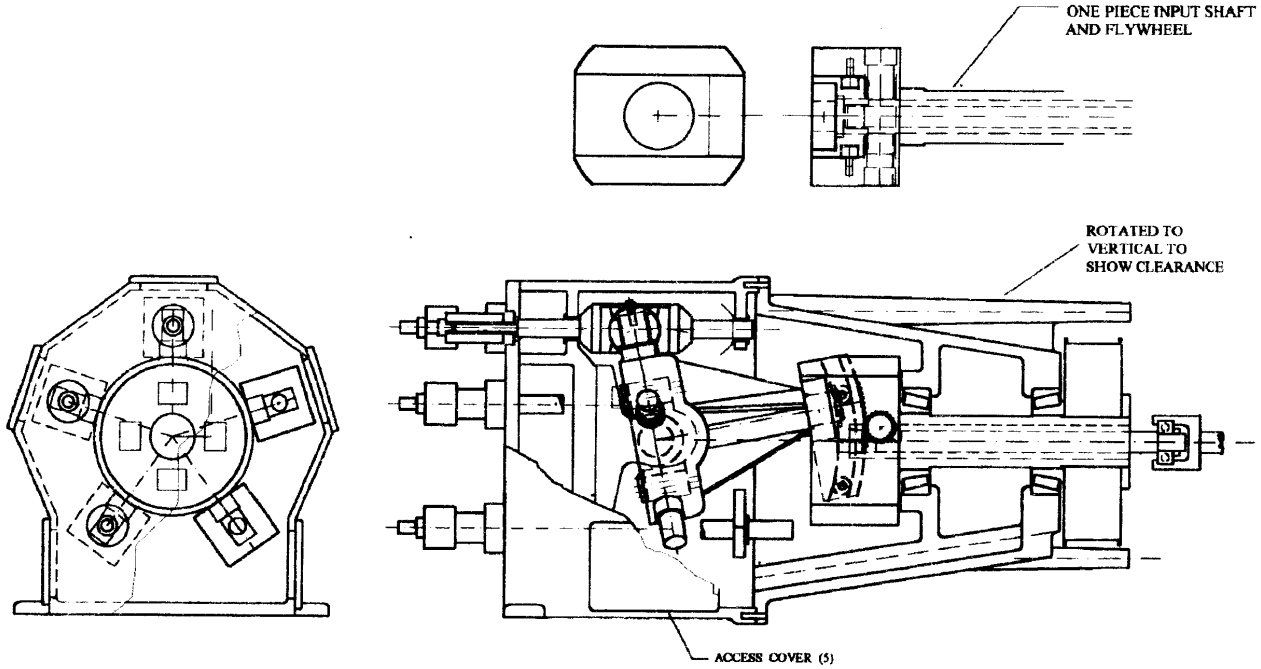
IEMDC: Pipeline Efficiency Gain Via Illustrative 16.7% Increased Line-Pack



IEMDC Details of Construction



Advanced Compression Concept: Sanderson Variable Stroke Concept



Summary

- **Electric Power Reliability and Availability Need Adequate, Flexible, Reliable Pipeline Compression**
- **Gas Turbine RAM and Condition Monitoring Technologies Benefit both Industries and Contribute to U.S. Energy Reliability**
- **Pipelines Need New Compression Concepts**
- **DOE has an Important Role to Play**